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THE PHYSICAL MECHANISM OF COMET OUTBURSTS: AN  
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During a series of impact experiments into regolith-like powders at the NASA Ames Research Center Vertical Gun Facility in 1976, I observed and filmed a unique anomalous event that may illuminate outburst mechanisms in comets.

During one test, a new batch of basalt powder (half the mass in particles less than  $800\text{ }\mu\text{m}$  in diameter) retained some air pressure while the vacuum chamber was being evacuated. As a result, the projectile impacted into gas-charged regolith. Instead of ejecting the normal, relatively negligible amount of debris, the disturbance triggered a major eruption that lasted for at least 17 seconds. The experimental results have been recently re-analyzed with reference to cometary phenomena.

Figure 1 shows a series of frames from this eruption experiment. The ejecta velocities of 150 to 300 cm/s would have been sufficient to drive debris into the coma of a comet nucleus smaller than a few kilometers diameter.

The event suggests a mechanism for comet outbursts, discussed briefly by Hartmann *et al.* [1]: The pore space in a layer of regolith, possibly with weak effective tensile strength, becomes gas charged as ice slowly sublimates. Once the effective tensile strength is exceeded by the gas pressure, the surface fails locally, triggering an eruption such as photographed here.

This model is consistent with the emerging view of regolith materials on comets [2, 3, 4], and is closest to the recent model of Rickman *et al.* [5]. The earlier models generally picture a more uniform flow of debris off the comet, not outbursts. Rickman *et al.* allow gas pressure to build until it matches the overburden pressure, followed by "instantaneous blow-off." They note that "...as soon as the mantle is found to be unstable, we consider it to be instantaneously swept away by the gas pressure."

The main new points made here are that the experiment gives a more realistic view of the blow-off process after surface failure occurs, and the present model gives a recharge mechanism that can explain recurrent outbursts on comets such as P/Schwassmann-Wachmann 1 and 2060 Chiron. In fact, the resulting jets resemble distinct jet structures in high-resolution comet comae, as seen in Figure 2.

These results are described in more detail in a paper submitted to *Icarus*. The work was supported by the NASA Planetary Astronomy and Planetary Geology and Geophysics programs.

References: [1] Hartmann, W.K., Cruikshank, D., and Degewji, J. (1982) *Icarus* 52, 377; [2] Brin, G.D. and Mendis, D.A. (1979) *Astrophys. Journ.* 229, 402; [3] Brin, G.D. (1980) *Astrophys. Journ.* 237, 265; [4] Fanale, F. and Salvail, J.R. (1984) *Icarus* 60, 476; [5] Rickman, H., Fernandez, J., and Gustafson, B. (1990) *Astron. Astrophys.* 237, 524.

## COMET OUTBURST MECHANISM: Hartmann, W.K.

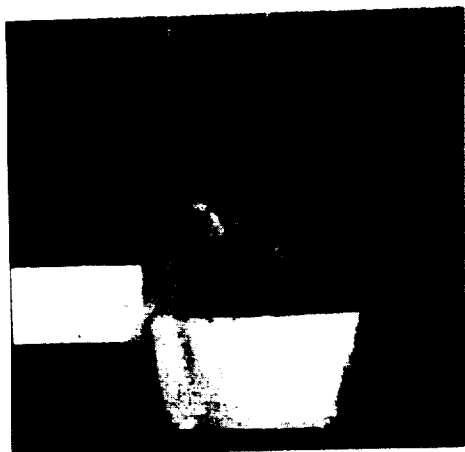
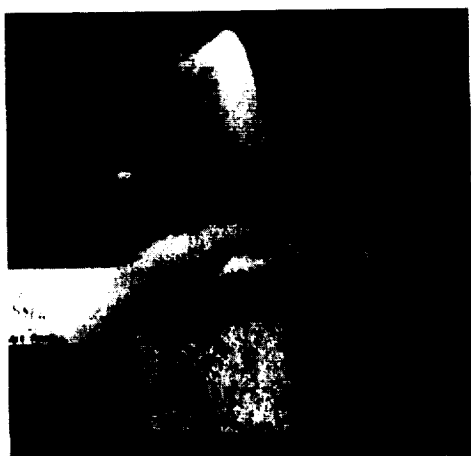
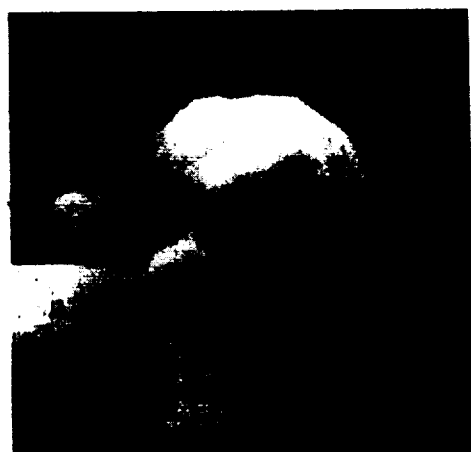


Figure 1 (left). Four frames from the film of the experimental eruption of gas-charged regolith powder *in vacuo*. Frame times are .07, .66, 1.32, and 3.32 seconds after impact. First frame shows jet of gas-driven debris (white) just emerging from impact site (impacts without gas jetting produced ejecta spray clouds of about this size). Last three frames show different states of continuing surges of gas-driven debris.

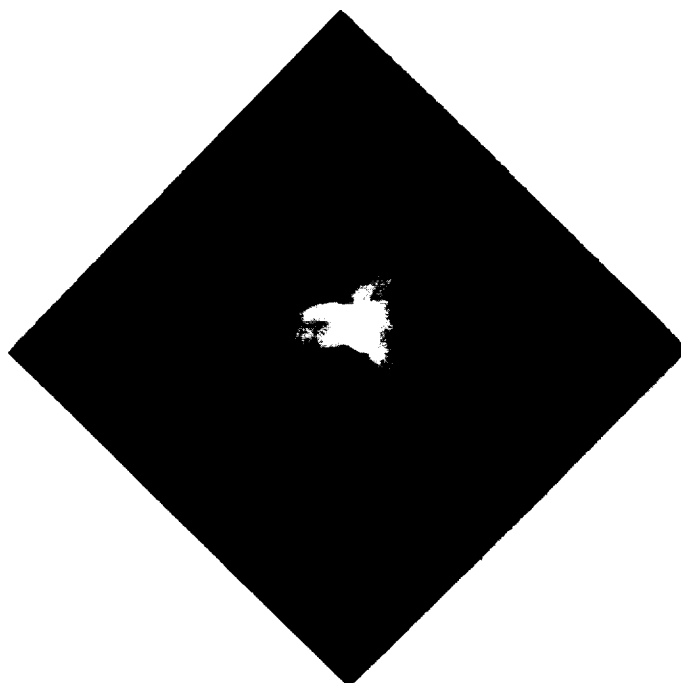


Figure 2 (above). Contrast enhanced view of Comet Halley, showing distinct jet structure in nucleus reminiscent of distinct jets generated by eruptive event in gas-charged regolith (Figure 1). (1986 March 15 image by Tapia and Senay, Boyden Observatory, processing by S. M. Larson; courtesy S.M. Larson, University of Arizona).